Bootstrapping Chord in Ad Hoc Networks: Not Going Anywhere for a While.

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3rd IEEE International Workshop on Mobile Peer-to-Peer Computing (MP2P '06)
Pisa, Italy, March 17, 2006
Peer-to-Peer and Ad Hoc Networks

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Outline

- Introduction
- Bootstrapping Chord: Problem definition
- Best-case and worst-case time complexity analysis
- Experimental validation
- Discussion and conclusions
Bootstrapping Chord

- Network creation and initial connection
- Sequential vs. simultaneous bootstrapping
- Consistency maintenance: stabilization
Bootstrapping Chord

- Network creation and initial connection
- Sequential vs. simultaneous bootstrapping
- Consistency maintenance: stabilization
Bootstrapping Chord

- Network creation and initial connection
- Sequential vs. simultaneous bootstrapping
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\[ j \quad k \quad l \]

successor
predecessor
Bootstrapping Chord

- Network creation and initial connection
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successor
predecessor
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Optimization
Bootstrapping Chord

- Network creation and initial connection
- Sequential vs. simultaneous bootstrapping
- Consistency maintenance: stabilization
Bootstrapping Chord

- Network creation and initial connection
- Sequential vs. simultaneous bootstrapping
- Consistency maintenance: *stabilization*

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Notation

Node labels
Notation

Node labels

Bootstrapping timeline
Best-Case Time Complexity
Best-Case Time Complexity

\[ t = 0 \quad \quad n-1 \quad \quad \ldots \quad \quad 2 \quad \quad 1 \quad \quad 0 \quad \quad n \]

(a) Best case  (b) Worst case

0 \quad 0 \quad 0

t = 0 \quad t = t_{stab} \quad t = 2 / t_{stab}
Best-Case Time Complexity

\[ t = 0 \]

\[ n-1 \rightarrow \cdots \rightarrow 2 \rightarrow 1 \rightarrow 0 \rightarrow n \]

\[ t = t_{\text{stab}} \]

\[ n-1 \rightarrow \cdots \rightarrow 2 \rightarrow 1 \rightarrow 0 \rightarrow n \]

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Best-Case Time Complexity

\( t = 0 \)

\( t = t_{\text{stab}} \)

\( t = 2 \cdot t_{\text{stab}} \)

\( n \)
Best-Case Time Complexity

\( t = 0 \)

\( t = t_{stab} \)

\( t = 2 \cdot t_{stab} \)

\( t = 3 \cdot t_{stab} \)

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Best-Case Time Complexity

\[ t = 0 \]

\[ t = t_{\text{stab}} \]

\[ t = 2 \cdot t_{\text{stab}} \]

\[ t = 3 \cdot t_{\text{stab}} \]

Time complexity: \( O(N) \)
Worst-Case Time Complexity
Worst-Case Time Complexity

\[ t = 0 \quad n-1 \quad \ldots \quad 2 \quad 1 \quad 0 \quad n \]
Worst-Case Time Complexity

\[ t = 0 \]
\[ t = t_{\text{stab}} \]

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Worst-Case Time Complexity

\( t = 0 \)

\[
\begin{array}{cccccc}
  n-1 & \ldots & 2 & 1 & 0 & n
\end{array}
\]

\( t = t_{\text{stab}} \)

\[
\begin{array}{cccccc}
  n-1 & \ldots & 2 & 1 & 0 & n
\end{array}
\]

\( t = 2 \cdot t_{\text{stab}} \)

\[
\begin{array}{cccccc}
  n-1 & \ldots & 2 & 1 & 0 & n
\end{array}
\]

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Worst-Case Time Complexity

Time complexity: $O(N)$
Worst-Case Time Complexity

\[ t = 0 \]
\[ t = t_{stab} \]
\[ t = 2 \cdot t_{stab} \]

\[ n-1 \quad \ldots \quad 2 \quad 1 \quad 0 \quad n \]

\[ n-1 \quad \ldots \quad 2 \quad 1 \quad 0 \quad n \]

\[ n-1 \quad \ldots \quad 2 \quad 1 \quad 0 \quad n \]

\[ n_{create()} \quad n_{join()} \quad n_{stabilize()} \quad n_{stabilize()} \quad n_{stabilize()} \quad n_{stabilize()} \]

\[ 0 \quad t_{stab} \quad 2 \cdot t_{stab} \]

\[ \text{ Tight bound: } \]
\[ \text{Time complexity } \Theta(N) \]

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Experimental Validation

- GloMoSim: Chord over AODV
- $t_{stab} = 30$ s
Experimental Validation

- GloMoSim: Chord over AODV
- $t_{stab} = 30$ s

Convergence of a 40-node network
Experimental Validation

- GloMoSim: Chord over AODV
- $t_{stab} = 30$ s

Convergence of a 40-node network
Conv. times against network size
Traffic Load
Discussion

- $k \geq 1$ join points: $\Theta(k + \left\lceil (N-k)/k \right\rceil) = \Theta(N)$
- Load distribution
- Selection of join points
- Simulations: *Mind the initial transient period*
Conclusions

- Self-organization in ad hoc networks
  - Distributed services: Peer-to-peer protocols
  - Spontaneous deployment
- Bootstrapping Chord
  - Centralized join points
  - Time complexity: $\Theta(\text{network size})$
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